THE DEVELOPMENT AND EVALUATION OF AN AUTOMATIC RATIO-DELAY DEVICE

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ABSTRACT

THE DEVELOPMENT AND EVALUATION

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This thesis develops the need for unavoidable delay allowances as an integral part of presently accepted industrial work measurement practices. From a discussion of these various techniques used to establish these unavoidable delay allowances, along with their respective shortcomings and good features, this conclusion is drawn: that a more economical procedure for obtaining information upon which to base unavoidable delay allowances can be developed.

The purpose of this thesis is to test this hypothesis: that an automatically-taken photographic ratio-delay study will yield results comparable with the results of a concurrent all-day time study.

The development of a device to make an automatic photographic ratio-delay study is described, and a complete description of its construction and operation appears in the appendix. The evaluation of this device consisted of collecting information about an actual industrial operation and comparing the results of this study with the results of a concurrent production study. A statistical test was made to determine the significance of the difference between the two sets of data. The differences were not considered to be significant. The conclusion is presented that, subject to certain limitations, the device provides a practical and useful means of collecting information upon which to establish unavoidable delay allowances.

CHAPTER I

INTRODUCTION

The Problem

The purpose of this thesis is to determine whether an automatically-taken photographic ratio-delay study will yield unavoidable delay allowance results comparable with those obtained from a concurrent production study.

What Allowances Are and Why They Are Needed

Allowances are an integral part of any well-engineered time standard. Allowances are made for irregularly occurring elements of work, for personal needs of workers, the unavoidable delays which occur in industrial production, and for fatigue. They are usually made on a flat percentage basis and are added to the total time required to perform a certain sequence of hand and body motions. Thus, the time required to perform a set of hand and body motions, plus the allowance time, constitutes the time standard.

This thesis is concerned only with the unavoidable delay allowance. Such delays are short, usually less than three minutes in duration, and occur with unpredictable frequency.

In the following discussion of authoritative literature, the term allowance refers to the general field of allowances. In general, the literature is concerned with the generic term allowances of which unavoidable delay allowances are a most important part. This discussion is presented to establish in no uncertain terms the need for accurate and economical allowances. The need for unavoidable delay allowances, therefore, will necessarily be apparent.

In 1883, Frederick W. Taylor, the originator of time study, in his first publication on scientific management, wrote of the need for allowances for personal needs and necessary delays. Taylor suggested that allowances should be arrived at through the use of time study. No mention was made in Taylor's early works of the length of the study, but it can be reasonably presumed that these studies were much longer than ordinary time studies(1). Curley, in 1935, proposed that continuous time studies, now known as production studies, be the basis for allowances. These studies were to be completely detailed; and all delays, necessary or otherwise, were to be carefully noted and recorded. Comparisons could then be made between operators and allowances made for all representative delays. This procedure, according to the author, eliminated the need for judgment and placed allowances on a factual basis(2).

Sylvester suggested three ways of establishing allowances. These possibilities were: to summarize past time studies, to make extensive production studies, or to use the ratio-delay technique. He believed that the most practicable procedure was the first mentioned(3).

Mundel mentioned three possible approaches to this problem: ratio-delay, all-day production studies, the memomotion study(4). Memomotion study is the taking of motion pictures at a much slower speed than ordinarily utilized, usually one frame per second.

Presgrave listed twelve types of allowances and analyzed each type individually(5). Each case was handled differently, and in the writer's discussion, there seems to be no common technique of how to establish these allowances. The author appears to believe that the time study department should be more concerned with the elimination of the causes for allowances than their determination.

Good industrial engineering practice demands that any legitimate delay, interruption, or malfunction of equipment be accounted for in the establishment of job standards. Claimed unfairness in the granting of allowances is a principal basis for present day time study and incentive grievances. Oftentimes, any delay time or time lost from production is recorded and paid for at the base hourly wage. Some incentive plans, however, stipulate the inclusion of delay times in the work standard. Present practice tends toward the latter, with predictable minor delays included in the work standard, and extraordinary interruptions recorded and paid for at an hourly rate as a separate remuneration.

It is in both the management's and the laborer's interests to establish proper and accurate allowances. Bellows, in 1945, presented several reasons why fair allowances were necessary. He observed that the employees' morale was affected by inadequate allowances, for it related directly to their pay. On the other hand, allowances which were too high constituted a gift to the worker, and were a direct cost to management. Production suffered with these overgenerous allowances since they tended to reduce the workers' incentive to produce(6).

Present Methods of Establishing Unavoidable Delay Allowances

Judgment.--One of the more common means of arriving at unavoidable delay allowances is judgment, or deciding in a more or less arbitrary way what the allowances should be. The appeal of this method lies in its ease, convenience, and rock-bottom cost. Justification for such a procedure is usually experience or expediency. Morrow wrote that many concerns resorted to this method of establishing unavoidable delay allowances because of the cost of making production studies(7). From an engineering standpoint, only dire emergency or very short production runs on a time standard would justify such a procedure. Much of the criticism of industrial engineering in general and time study in particular is engendered by just such ill-conceived means as this.

Production Studies.--Production studies are the most commonly used means of obtaining information for the calculation of unavoidable delay allowances. A production study is essentially an all-day time accounting of the operator's activities, with particular attention being paid to delays and interruptions. Instead of recording the detailed motions of the operator and time required for these motions, the observer simply records "operator working" and the nature and extent of the delays and interruptions.

Production studies usually continue for the entire working day and in some instances on a twenty-four hour per day basis. Usually, sufficient information can be gathered in the course of two weeks' study to calculate reasonable, unavoidable delay allowances. The disadvantages of this procedure are unpredictable accuracy and high cost. Moreover, no theoretical basis for establishing the length of any given study has been developed. A time study observer is usually employed to make such observations, and his work is not completed at the end of the working period. Generally, one hour per day must be allowed this observer for summarizing his study. An additional disadvantage is the tedious and boring nature of the observation work, sometimes causing error in evaluating and posting delays.

Ratio-Delay.—The third important method of determining unavoidable delay allowances is the ratio-delay observation technique. In the words of its originator, L. H. C. Tippett, the ratio-delay method of determining allowances is "a snap-reading method of making time studies"(8). It is interesting to note that this method originated from a desire to improve upon subjective procedures used to establish unavoidable delay allowances in the textile industry in Great Britain.

Tippett's approach was made with the desire of overcoming the tedious and costly limitations of the all-day production study. Another factor was the psychological bloc felt by the worker while under constant observation. Still another shortcoming was the possibly inaccurate information gathered from a production study made under rapidly changing conditions, and the new method was to overcome this difficulty along with those already mentioned.

Tippett evolved a procedure of taking a large number of snap-readings of machines, at random intervals, and recording their status, either working or idle, and the cause of the idleness. Through use of Tippett's method, the percentage of the readings that record the machine as working will approach the percentage of the time that the machine is producing. Tippett went on to say that if the readings are randomly distributed over a sufficiently long period, the percentage will hold regardless of the nature or extent of the delays.

The operation to be studied should be analyzed, and homogenous groupings of similar delays should be established. The determining factor in the number of groups is, of course, the same as for production study: the breakdown should be made to the extent that it will be subsequently applied to production standards.

In making a ratio-delay study, Tippett suggested adherence to several principles. The observation should be made in a random manner, and the decisions (as to whether working or idle and, if idle, the cause) should be made instantaneously if possible. He advocated a specific spot from which to take observations in order to preclude anticipation of the operator's movements.

The number of observations to be made depends upon the occurrence and variation of the delays found. In general, the literature available on the subject emphasizes the need for a large number of observations. Petro said that fewer than a thousand observations would be of little value(9). Morrow, in general agreed with the large number of observations school of thought, but contended that the results of as few as three hundred observations can be used, if the delays are binomially distributed(10). Binomial distribution delays are commonly encountered in interference resulting from multiple-machine assignments. It is interesting to note that neither Petro nor Morrow specified the number of operators or machines to be observed.

Petro quoted a unique study made by an industrial time study staff. Members were instructed to note the conditions surrounding a particular job while on their way to make a study or returning from a study. The results of this ratio-delay study compared favorably with a continuous production study made for almost three hundred hours(11).

Barnes and Correll listed the precautions that should be taken with a ratio-delay study in order to avoid bias. The authors arrived at these recommendations after a comprehensive investigation of ratio-delay application in actual industrial operations.

1. Clearly define productive and delay status; the decision regarding status must be made instantly. Delays should not be anticipated.

2. Take the observations at truly random intervals, and avoid periodic stops such as rest periods.

3. Long delays should be recorded only once.

4. The use of the results should be considered in determining periods of observations. If they are to be applied to allowances for incentive work, then observations should be made while incentive work is being done.

5. Sufficient observations should be made to decrease the sampling errors to within acceptable limits. The greater the percentage delays, the greater the number of observations needed.

6. Production records should be checked for the period of the study to determine if results were obtained during a normal work period.

7. Inform the workers that the study is being made and instruct them to work as usual.

8. In calculating the results, only homogenous groups of data should be used(12).

Barnes and Correll also advised that the observations should cover the entire work day and work week. During this period a log should be kept to insure the lapse of adequate time between observations so that they will be truly independent. This record is necessary because the ratio-delay theory is based upon the number of delays, rather than their length(13). Schaeffer has suggested that several operators should be studied on the same observational trip to reduce the cost of the study(14).

Abruzzi, in his recent book, Work Measurement, pointed out several interesting aspects of the application of the ratio-delay allowance determination method. He advanced the idea that the ratio-delay technique is concerned with the grand characteristics of delays, and offered an explanation of disagreements in Morrow's published data on ratio-delay results with this idea. Grand characteristics refer to delays experienced over a long period of time. Local characteristics refer to delays over a much shorter period. Abruzzi maintained that since ratio-delay is concerned with grand characteristics, observations based upon one operator are not valid(15). His studies on local stability and grand stability establish the value of grand stability studies: that is, many operators should be observed over a lengthy period of time.

Tippett points out that there are two kinds of errors present in ratio-delay study: systematic and random. Systematic errors can be reduced by making observations at truly random times with the operator's confidence. When systematic errors are eliminated, random variations between repeated determinations of a percentage are usually only slightly greater than may be expressed by the binomial law; hence it can then be used to calculate the standard error of the results.

If a large number of observations are made, random variation is reduced to a minimum; but systematic errors become increasingly important. Unless exceptional precautions are taken, the total error is not likely to be reduced much below two percentage points. Exceptions occur where the percent measured is very small or very large (between zero and five per cent, or between ninety-five and one-hundred per cent) or when comparisons are being made under conditions with constant systematic errors(16).

The magnitude of the randon variation can be computed from the formula:

$$\sigma = \sqrt{\frac{p(1-p)}{N}}$$

where σ = standard deviation of a percentage

p = the percentage expressed as decimal

N = the number of observations

The satisfactory limits of accuracy of industrial ratio-delay studies have been mentioned by Barnes and Correll as being five per cent(17). This statement means that the true value of the unavoidable delay percentage allowance should be in the range from the estimated value, plus five per cent to the estimated value, minus five per cent. For example, where the unavoidable delay allowance was determined to be twenty per cent, or .20 of the total time standard, the true value for the allowance would fall somewhere between 0.15 and 0.25 of the total time standard.

Experimental Procedures for Establishing Unavoidable Delay Allowances

Dwyer's Work.--In 1950 at Georgia Institute of Technology, Dwyer executed a research project which pointed out the usefulness of a movie camera, activated for short sequences of frames, for the collection of certain types of data(18). Since the activation intervals were regular and equally spaced, his study did not meet the requirements of the ratio-delay technique. However, his work led to the further exploration mentioned below.

Pickett's Work.--Pickett, in 1952, investigated a photographic ratio-delay technique. His procedure consisted of taking one frame, at random intervals, with a movie camera, and making a simultaneous, visual ratio-delay study(19). Pickett's findings were negative, for the following reasons:

1. The two studies did not satisfactorily agree.
2. The studies were of insufficient duration.
3. Simultaneous observations were difficult to achieve.

His work, along with that of Dwyer, prompted this further investigation into the photographic methods of making modified ratio-delay studies. The writer is of the opinion that the single frame release procedure used by Pickett did not provide enough information regarding the actual state of the operation in question. The writer further believes that a series of pictures will convey the requisite information so that photographic ratio-delay will agree more closely with the actual situation. Taking only one frame at a time does not make full use of the capabilities of a camera. The utility of the movie camera lies in its provision for the portrayal of motion; and if only one frame is exposed at a time, no use is made of this unique feature.

CHAPTER II

THE DEVELOPMENT OF THE AUTOMATIC PHOTOGRAPHIC RATIO-DELAY DEVICE

In the preceding chapter, an attempt has been made to explain the superiority of the ratio-delay observation technique as a means for gathering information upon which to base unavoidable delay allowances. Ratio-delay provides information of known accuracy limits more economically and with less tediousness than does the production study. Production studies are subject to many errors of omission or commission, due largely to their exceedingly tedious nature. The elimination of this type of drudgery is in itself a worthy cause; for it not only frees the time study observer from the yoke of constant attention, it frees the industrial worker from constant surveillance. Thus is established the superiority of the ratio-delay technique for most industrial purposes.

The earlier work of Dwyer, with a modification of Mundel's memo-motion technique, and Pickett's experimentation with a modification of the ratio-delay technique, prompted the writer to this further experimentation. Ratio-delay has been shown to be superior to production study; and Pickett's and Dwyer's work pointed to a procedure which, for some uses, could be superior to ratio-delay.

The basic difference between the ratio-delay observation technique and a photographic modification of this technique should be clearly understood. Ratio-delay studies are limited only by the capacity of the observer and the time available for studies. A photographic modification of this technique is limited by the capabilities of the camera and its control mechanism which can accomplish only a predetermined sequence of actions at a fixed location. Thus, the use of a photographic ratio-delay technique is limited to the observation of one or, at most, a small group of machines and/or workers.

Although the usefulness of an automatic photographic ratio-delay device is not universal, there are many types of industrial activities where such a device could be substituted for the ratio-delay technique generally employed. In individual or crew work confined to a relatively small area, a photographic procedure could be used. The only necessities for the economical application of such a procedure would be a camera providing a clear image over the entire work area and unrestricted field of vision for the camera.

An apparatus to make a photographic ratio-delay study was developed. This apparatus consisted of a device for producing random impulses, an electronic timing circuit, a power supply, and a sixteen millimeter gun camera. A description of the construction and operation of this device appears in the appendix.

CHAPTER III

PROCEDURE

Description of Procedure

In order to evaluate the automatic photographic ratio-delay device, it was necessary to place it in operation in an industrial plant to make a ratio-delay study and a concurrent production study. A textile weaving operation was selected, and a preliminary survey was made to familiarize the writer with the operating procedures of this mill.

The Operation

The weaver's assignment consisted of fourteen semi-automatic looms weaving drapery fabrics. These looms, once started, continue to run until a strand of yarn breaks, or a mechanical malfunction arises, or the warp or filling supply is exhausted. No operator attention is required other than that of cursory inspection and perhaps occasional work on the warp threads as they become visible. If a yarn break occurs or a mechanical difficulty arises, the loom stops automatically and must be serviced before being restarted. The weaver is on the job eight hours continuously, for there are no scheduled rest intervals or lunch periods. The weaver is paid on a piece rate, with penalties for poor quality cloth in excess of a fixed allowance for seconds. Thus, the operator has a financial incentive to reduce the loom down time to as low a figure as possible, consistent with acceptable quality.

The weaver studied in this thesis research was provided with a number of services by indirect laborers. Battery hands tended the filling supply. Smash hands repaired breaks involving more than yarn strands. Loom fixers were available merely by raising an indicator on a faulty loom. Warp changers were responsible for replacing exhausted warps. Therefore, the weaver could concentrate his efforts on rapidly restarting the looms.

The cloth being produced was 118 strands of yarn per inch of warp, 39 picks (strands of yarn) per inch of filling; and the weight was 1.59 yards per pound. Draper XD model looms were used, and the cloth was 52 inches in width. The warp supply was 1,450 yards in length.

Workplace Layout

The fourteen loom assignment was arranged in two lines, each seven looms in length, facing each other. Thus the weaver could walk the seventy foot aisle between the loom fronts and observe and repair breaks as the occasion demanded.

The camera and control mechanism were mounted on a platform about fifteen feet from the end of the loom aisle, and the camera was focused on the two end looms. The camera was set on a five foot tripod. The main axis of the camera was on the center line of the assignment, tilted slightly downward, for the platform was about two feet higher than the main mill floor. See Figure 1 for the workplace layout.

The Production Study

A production study was made of the operation of two looms at the same time that the ratio-delay device was functioning. The production study was made on all three shifts since the mill operated on a twenty

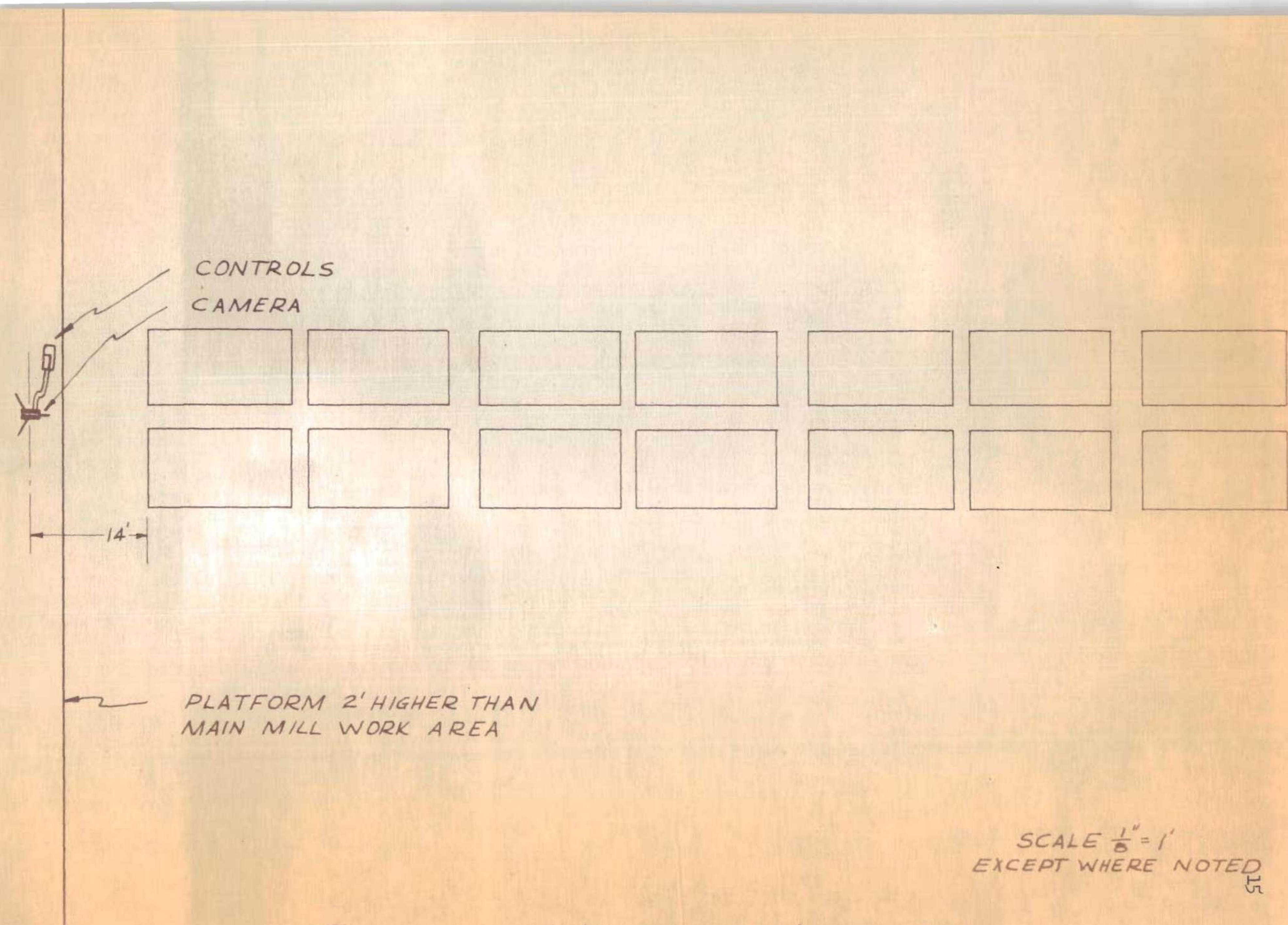

FIGURE 1 WORKPLACE LAYOUT

four hour per day schedule. This study covered thirty four and one-half hours and recorded all the down time experienced by the two looms observed by the ratio-delay device, along with the reason for their non-productive status. Several categories of delays were noted:

Weaver Unavailable means that the loom was not producing, the weaver not being available for servicing. Most of the delays arose from interference, or the preoccupation of the weaver. On two occasions, the weaver was talking with a supervisor or a friend; but this time was so insignificant that it was included in the interference total.

Weaver Service was broken down into three groups: warp service, filling service, and mechanical service. The warp service consisted of locating and retying the broken thread; drawing it through the proper spaces in the drop wires, harness and reed; and restarting the loom. The filling service consisted of locating the broken strand of yarn in the shuttle, replacing the shuttle, and restarting the loom. The mechanical service consisted of minor adjustments, if required, and restarting the loom. Most of the mechanical services were merely restarts after a slam off, for which no cause is apparent.

Warp Out means that the warp was being replaced by indirect laborers. This operation required approximately eighty minutes, and was accompanied by a thorough cleaning and lubrication of the loom.

Fixing refers to service rendered by mechanics to looms that were out of adjustment, or required the replacement of broken parts.

Doff Cloth means that the loom was out of service for the removal of a roll of finished cloth.

Camera Notes

Lighting of the weaver's assignment of looms was provided by two lines of fluorscent fixtures, one over the top of each line of looms. This lighting arrangement provided sufficient illumination for the exposure of sixteen millimeter Kodak Super XX film without the need for flood lights or other auxiliary light sources. A lens setting of f 1.5 was used. A total of forty-five feet of film was intermittenly exposed, with a standard camera speed of sixteen frames per second.

CHAPTER IV

RESULTS

Evaluation of Films

The film strip was projected with the aid of a single frame release projector, and the status of the operation was determined. Since the looms had two starting levers which were in vertical position during normal operation and inclined 30° when stopped, a decision as to running or stopped could be made instantly. If the loom was not running and the weaver could be seen working on an adjacent machine, the classification was interference. If an indirect laborer was seen to be working on the loom, the classification was machine repair, warp change, or doff cloth, depending on the situation. The weaver service was broken down into three categories as mentioned in the preceding section; but because of the difficulty in classifying some frames, the total was shown in the results as weaver service.

A short strip of film is displayed on the following page. The blank frames resulted from the stoppage of the shutter in an open position following the exposure of a series of frames.

Table of Results

A table of results appears on the second page following. A complete accounting of all observation time and occurrences from the film strip is included.

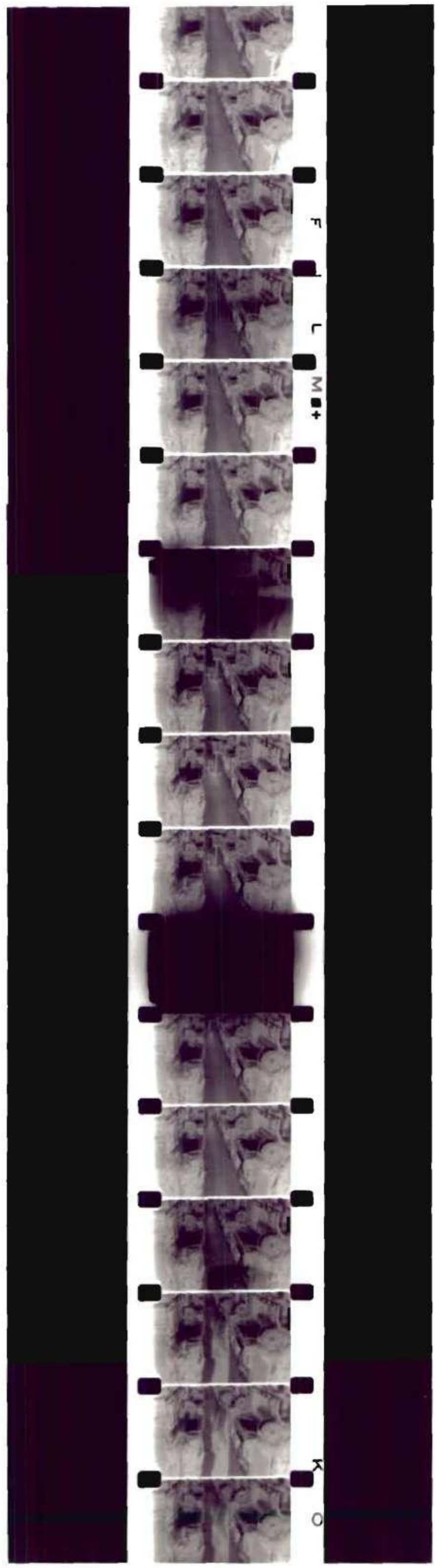

Fig. 2 - Typical Film Strip

Table 1. Results of Production and Ratio-Delay Studies

	Production Study	Ratio-Delay Study
Length of study	34.5 hrs.	34.5 hrs.
Machines studied	2	2
Machine output	578,000 picks	Not applicable
Machine output at 100% eff.	669,980 picks	Not applicable
Machine efficiency	86.27%	88.92%

	Production Study Distribution of Observation Time		Ratio-Delay Study Distribution of Occurrences	
Operation	Minutes	%	Observations	%
Machine producing	3571.58	86.27	578	88.92
Interference	227.87	5.50	44	6.77
Operator service	162.49	3.93	18	2.77
Machine repair	74.74	1.80	8	1.23
Warp change	70.00	1.69	1	.15
Doffing cloth	11.29	.27	1	.15
Unaccounted for	22.03	.54		
Totals	4140.00	100.00	650	100.00

Comparison of Results

Table II presents a comparison of the two sets of results, photographic ratio-delay and production study. The observed frequencies can be seen to closely approximate the expected frequencies. The expected frequencies for the various operations were obtained by multiplying the known time distribution percentages by the total number of observations made by the device.

The χ^2 test was used to determine the level of significance of the difference between the known conditions found from the production study and the sampling of these conditions by the ratio-delay study.

The comparison of results details all of the mathematical steps involved in obtaining a value for χ^2, which was calculated from the equality:

$$\chi^2 = \Sigma \left[\frac{(O-E)^2}{E}\right]$$

were χ^2 = the statistic

O = observed operation frequency

E = expected operation frequency

Σ indicates the summation over all operations

This equation is to be found in Industrial Experimentation(20). The table for the probability associated with values of χ^2 for three degrees of freedom are to be found in the same reference.

The χ^2 test did not include two operations: warp change and cloth doffing. Since these operations are regular events, they do not come within the scope of ratio-delay theory(21).

Table 2. Comparison of Results

Operation	Distribution of Production Study Time %	Expected Frequency Distribution E	Observed Frequency Distribution O	O-E	$(O-E)^2$	$\frac{(O-E)^2}{E}$	Probability that difference in two sets of data is due to chance causes when DF=3 P
Machine Running	86.27	516	578	17	289	.515	
Interference	5.50	36	44	8	64	1.778	.11
Operator Service	3.93	26	18	-8	64	2.462	
Machine Repair	1.80	12	8	-4	16	1.333	
Warp Change	1.69	11	1	NOT APPLICABLE			
Doffing Cloth	.27	2	1	NOT APPLICABLE			
Unaccounted For	.54	4	0	NOT APPLICABLE			
Total	100.00	562	650			χ^2 = 6.088	

Discussion of Results

It is believed that the results of this study are satisfactory. The probability that the difference in the two sets of data is due to chance causes is 0.11. This value is well outside of the usual statistical limitation of 0.05. Perhaps the nature of this example is such that fewer than the usual number of observations yields satisfactory results. The literature abounds with warnings about less than several thousand observations, and many writers think that one thousand observations are the minimum.

Discussion of the Operation of the Device

In general, the automatic ratio-delay device functioned properly. Some difficulty was noticed near the end of the test when the drum contact did not always make an electrical connection. The high relative humidity in the mill, approximately eighty-five per cent, and the flying lint, probably caused this malfunction to occur. The high moisture content of the air caused rust to form, and the lint concentration in the air tended to accumulate on the contacts.

A total of forty-five feet of film was exposed, and the average number of frames per impulse was four. The number of frames per impulse varied from one to six, on one occasion numbering eight. Many times the shutter remained open after taking a series of frames, and the resulting blank frame was a sizeable help in determining the beginning and ending of a sequence of frames. Where a blank frame did not appear, the first frame of a sequence was over exposed slightly; and the last frame was under exposed slightly. These conditions made for ease of analysis.

CHAPTER V

CONCLUSIONS

The purpose of this thesis is to determine whether an automatically taken photographic ratio-delay study will yield results comparable with those from a concurrent production study.

Within the framework of the following limitations,

1. The length of the study was thirty-four and one-half hours;

2. The number of sequences of frames was six hundred and fifty;

3. The number of machines observed was two;

4. The characteristics of the semi-automatic machines studied;

the conclusion is presented that the data collected by the automatic photographic ratio-delay device agrees satisfactorily with the data from the production study. Therefore, it is evident that the purpose of this thesis has been affirmatively fulfilled.

It is probable that better agreement would have been obtained with a larger number of observations. In practice, the choice would be between accepting the data as they stand, or collecting more observations.

Some of Pickett's conclusions drawn from experimental work of a similar nature are appropriate for inclusion here:

1. The initial cost of the equipment for a photographic ratio-delay study is high. However, the use of this equipment for other purposes helps offset the initial outlay.

2. The camera with the time lapse drive* would require a mounting that would not be disturbed during the day.

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*Pickett's term for a scheme similar to the automatic photographic ratio-delay device.

3. The amount of machine utilization can be easily determined in any case where machines are being used.

4. A time lapse drive actuated camera requires very little attention during the course of a working day(22).

To these conclusions, the following can be added:

1. The cost of an automatic photographic ratio-delay study is small, compared with a production study. Five dollar's worth of film would suffice for an entire work week, at the exposure rate used for this thesis. The evaluation of the film could be accomplished in two hour's time, and without the aid of additional equipment. A comparable production study made by a technician would cost in the neighborhood of sixty dollars. Thus a rough ratio between costs, allowing for summarizing the production study, would be about seven to one. However, a production study could be made on more than the two machines used for this thesis. This additional information would reduce the cost ratio advantage of photographic ratio-delay. However, allowing for this reduction, it is probable that the photographic ratio-delay procedure would still enjoy a considerable cost advantage over production study.

2. The analyst should be familiar with both the operation and the personnel assigned to the operation. Film analysis for this thesis would have been much more difficult had the analyst not been able to recognize individual workers and their particular assignments.

3. A short sequence of frames is easier to analyze than is a single frame. If the starting handles of the looms were obscured, then comparison between adjacent frames revealed differences in location of moving parts, and this discrepancy indicated that the loom was in operation.

4. Some difficulty was encountered in film analysis because of the workers' desire to "get into the act." Several sequences were useless because a group of workers had gathered to see what was taking place. This inordinate curiosity might be circumvented by a completely enclosed mechanism.

5. The use of a wide angle lens would have resulted in the collection of additional information. The backs of the looms were not visible, and valuable information as to the type of service being rendered by the weaver was lost.

6. The mounting of the camera tripod on a platform two feet higher than the main floor of the mill was a decided advantage. This additional height enabled the complete weaver's assignment to be visible on the film strip, even though somewhat indistinct at the far end.

CHAPTER VI

RECOMMENDATIONS

It is the opinion of the writer that the results of this thesis demonstrate the feasibility of the automatic photographic ratio-delay technique for certain types of industrial studies. This technique is subject to certain limitations, such as the observation of a relatively small area and the limitations inherent in any kind of automatic machinery. As a primary source of information upon which to base unavoidable delay allowances, this technique is believed to be equal to production studies in the analytical aspect, and superior in the economic aspect. A technique of this kind provides information of known accuracy limits and is not subject to the variations inherent in human observations made under rapidly changing conditions for long periods. Human judgment is postponed, to be done at the leisure of the analyst, far from the pressures of the production floor.

It is recommended that further research be done along these lines:

1. The evaluation of other sources of random impulses. A Geiger Counter has been used in the textile industry for manufacturing decorative yarns containing slubs, or large places. The counter is actuated by cosmic rays, randomly distributed in nature. Such a device might well be used in place of a predetermined sequence of random numbers. Also, a tape or disc recording system might be advantageous, particularly if it contained a variable speed drive.

2. The use of other types of cameras. A solenoid operated release for Cine Eastman Special would provide a flexible means for making photographic ratio-delay studies. The writer expended considerable time attempting to perfect such a device, but met with no success. However, a different approach to the problem might easily yield the desired results.
3. The development of a device to connect with stop motion circuits of semi-automatic machines. Such a device would be ideal for an operation such as that studied in this thesis. Operated as a memomotion technique, it should perform the function of a time study observer.
4. An investigation into the theoretical and practical considerations involved in sample size required for automatic photographic ratio-delay studies.

REFERENCES

(1) Taylor, Frederick W., Shop Management, The American Society of Mechanical Engineers. New York, 1903. As part of Scientific Management, Harper. New York: 1911, p. 115.

(2) Curley, W. E., "The Problem of Allowances in Time Study," Taylor Society Bulletin and the Society of Industrial Engineers, Vol. 1, No. 3, March, 1935.

(3) Sylvester, L. A., The Handbook of Advanced Time Motion Study. New York: Funk and Wagnalls Company, 1950, p. 207.

(4) Mundel, Marvin, Motion and Time Study, Principles and Practices. New York: Prentice Hall, 1950, p. 348.

(5) Presgrave, Ralph, The Dynamics of Time Study. New York: McGraw Hill, 1945, p. 195.

(6) Bellows, F. H., "Methods of Determining Fatigue and Other Allowances," Proceedings of the National Motion and Time Study Clinic, 1945, p. 16.

(7) Morrow, R. L., "Ratio-Delay Study," Mechanical Engineering, Vol. 63, April, 1941, p. 302.

(8) Tippett, L. H. C., "Statistical Methods of Textile Research. A Snap Reading Method of Making Time Studies of Machines and Operatives in Factory Surveys," Journal of the Textile Institute Transactions, Vol. 26, February, 1935, p. 51.

(9) Petro, J. S., "Using Ratio-Delay Studies to Set Allowances," Factory Management and Maintenance, Vol. 106, October, 1948.

(10) Morrow, R. L., "Ratio-Delay Study," Mechanical Engineering, Vol. 63, April, 1941.

(11) Petro, op. cit.

(12) Barnes, R. M. and D. S. Correll, "Industrial Application of the Ratio-Delay Method," Advanced Management, Vol. 15, August, 1950, p. 10.

(13) Ibid.

(14) Schaeffer, E. H., "Observation Ratios: A short Cut to Time and Cost Analysis," Factory Management and Maintenance, Vol. 99, July, 1941, p. 53.

(15) Abruzzi, Adam, Work Measurement, New York: Columbia University Press, 1952.

(16) Tippett, op. cit.

(17) Barnes, op. cit.

(18) Dwyer, J. S., and R. N. Lehrer, "Photographic Job Study," The Research Engineer, March, 1952.

(19) Pickett, R. E., Evaluation of a Photographic Ratio-Delay Technique, M. S. Thesis, Georgia Institute of Technology, Atlanta, 1952.

(20) Brownlee, K. A., Industrial Experimentation, Chemical Publishing Company, New York, 1949, p. 40 and p. 182.

(21) Barnes, op. cit.

(22) Pickett, op. cit.

(23) Proschon, Frank, "Use of Random Numbers," Industrial Quality Control, Vol. 9, July, 1952.

APPENDIX

CHAPTER VIII

APPENDIX

DESCRIPTION OF EQUIPMENT

General

The apparatus consists of three major components: a source of random impulses, a timing circuit, and a movie camera. These components are connected as shown in Figure 3. The source of random impulses provides an electrical contact that when closed sets the time delay circuit in operation. The time delay circuit closes a relay which starts the camera. Upon the elapse of a predetermined time interval, the relay breaks the circuit, and the camera stops.

The Random Generator

The random generator, shown in Figure 4, consists of a six inch drum, nine inches long, driven by a synchronous electric motor through a gear train. The drum is wound with laminations of flat steel strapping on a one-half inch pitch such that a tooth is formed by the six thicknesses of steel. An aluminum slide is in contact with the tooth on both sides, and guide rods serve to keep the slide in the proper position relative to the drum. A lucite insulator, mounted on the slide, holds a brush type contact; and one lead goes from this contact to the time delay circuit. The other lead, a ground from the chassis of the timing circuit, is connected to the main bearing of the drum.

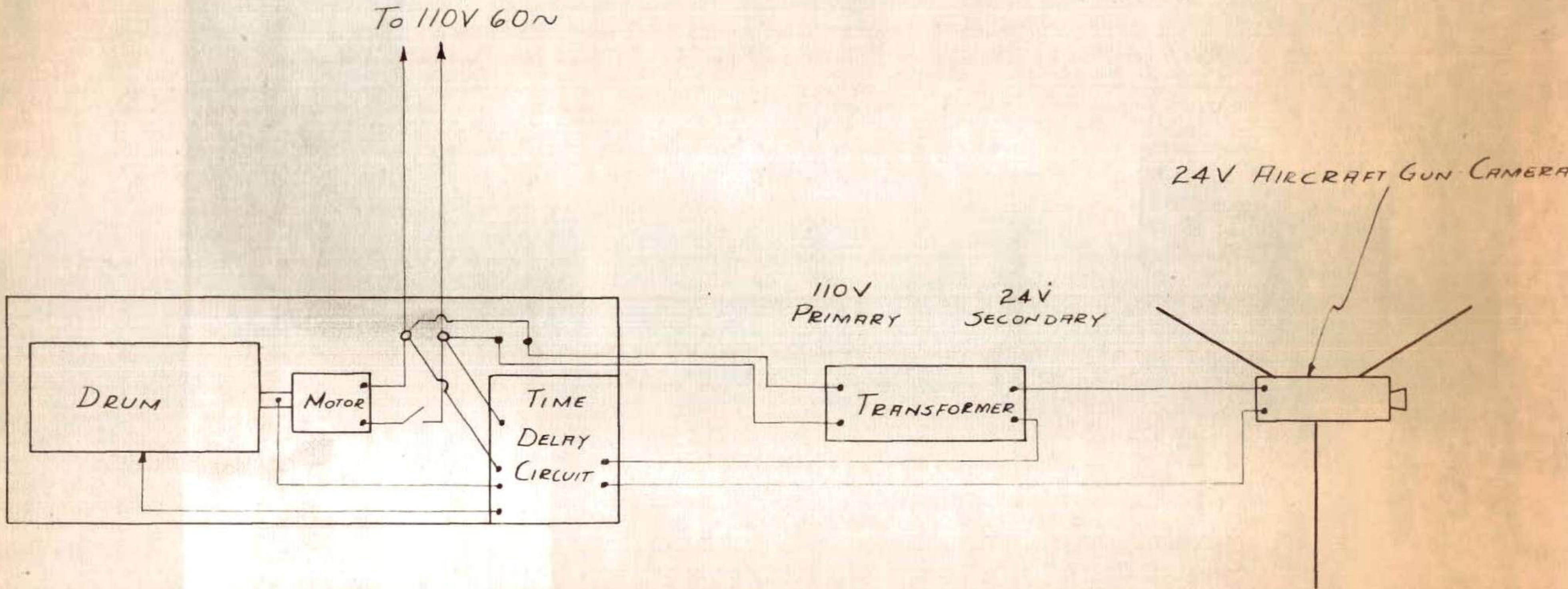

Figure 3 - General Wiring Diagram

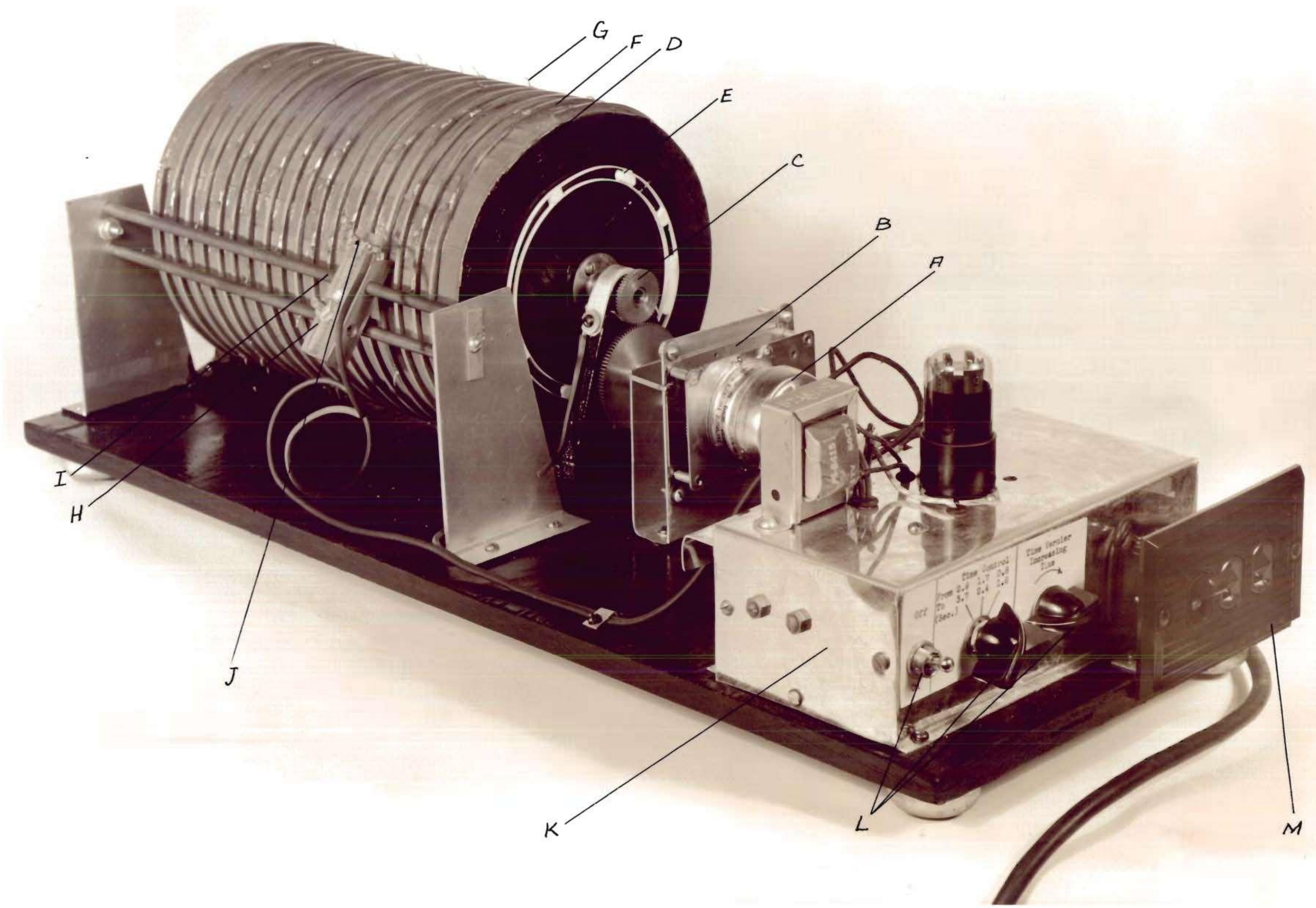

FIGURE 4 - RANDOM GENERATOR

Figure 4

This picture shows the random generator and the index letters to the various components. (A) is the motor which drives the drum. This is a synchronous, 110 volt, 60 cycle, 3 watt motor similar to the type used for large electric clocks. (B) is the gear box and coupling. The gear box consists of a clock drive, with all auxiliary gears removed, and the minute hand drive shaft slotted into the main shaft which drives the drum. This main shaft is supported by two ball bearings to reduce friction and mounts a gear which meshes with a gear mounted on the drum shaft. (C) is the 2:1 gear ratio connecting the drum with the main shaft. This set of gears causes the drum to rotate two revolutions per hour. (D) is the drum, previously described. Made from a tin can, with plywood ends, it is supported by ball bearings. (E) is a balance ring with lead weights placed so that they balance the drum, allowing it to rotate freely. (F) is the tooth, previously described as consisting of six laminations of .100x.0125 steel strapping. This tooth is continuous and eighteen turns in length. It also provides a mount for the trip pins. (G) is a trip pin, of which there are 102 mounted at random intervals along the tooth. The placement of these pins was determined by a table of random numbers(23). (H) is the slide which rides on the tooth. The contact switch is mounted on the slide in such a way that a trip pin makes contact and the contact slides over and springs free when the drum has rotated past. (I) is the guide rod which pierces the slide and serves to keep the slide properly positioned at all times. The lower guide rod serves to keep the slide from rotating about the upper guide rod. (J) is the contact spring mounted on a lucite insulator. (K) is the time delay circuit, described below.

(L) are the controls for the time delay circuit. (M) is the outlet for the camera circuit and also an outlet for 110 volts for the camera supply transformer.

The Time Delay Circuit

The time delay unit is pictured in Figure 3 and a circuit diagram appears in Figure 5. It consists of a power supply transformer, a control section, and a switch control section.

The power supply transformer provides 6.3 volts for the indirectly heated cathode and 150 volts for the plate. A selinum rectifier and and condenser-resistor combination supply the 150 volt direct current required by the plate. In the plate circuit, the relay is connected in series so that a current of 4 millamperes will trip the relay.

The time control consists of four fixed resistors and one variable resistor, enabling the circuit to provide intervals from 0.8 seconds to 3.7 seconds in stepless fashion. A seven and one-half volt battery supplies the negative bias needed to cut off the tube, and this battery is in series with the resistors.

The switch section is composed of a seven and one-half volt battery used to charge the two large capacity condensers and a resistor to reduce the current in this branch.

In operation, the minus seven and one-half volt bias is sufficient to keep the plate current at about one millampere. When the contact switch is closed, the plate current immediately rises to around eight millamperes because of the sudden change in bias; and the condensers begin to charge. As the charge on the condensers increases, the bias begins to decrease and to approach the minus seven and one-half volt

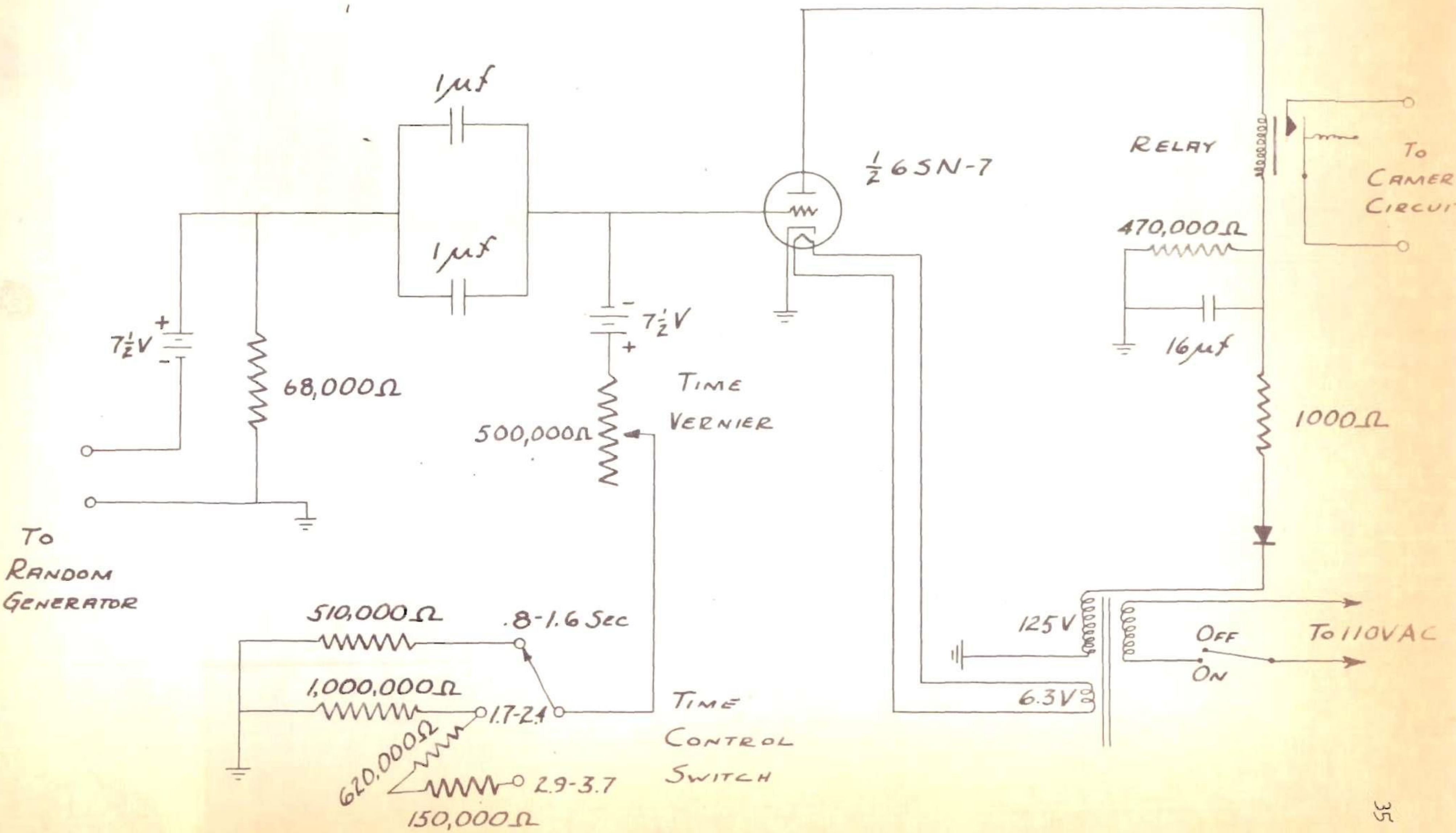

Figure 5 -Diagram of Time Delay Circuit

level. This condition is accompanied by a reduction in plate current; and when about three millamperes are reached, the relay opens. The bias further reduces to minus fifteen volts when the contact switch is opened. After about ten seconds have elapsed, the bias returns gradually to the minus seven and one-half volts which is normal for the open switch condition. This ten second interval is the "recovery time" of the circuit.

Note that the opening of the drum switch has no effect on the circuit except when the relay is closed. This never occurs during normal operation, for the trip pins are long enough to maintain contact for about one minute.

The Camera

The camera used for this study was a sixteen millimeter GSAP (gun sight aiming point) type. This camera was designed for aircraft usage and, consequently, is not the most suitable for industrial purposes. The camera was originally equipped with a f 3.5 lens and no adjustment for focus. This lens was removed and replaced with a f 1.5 lens with adjustable focus.

Original plans called for the use of a Cine Eastman Special II, but the control of the camera presented problems that could not be overcome in the limited time available. The development of a control device for the Cine Special might well be the subject for further investigation, for the flexibility of this camera makes it idea for industrial use.

The GSAP camera requires a source of twenty-four volts, and this need was met by using a transformer with one hundred ten volt primary and twenty-four volt secondary windings. As shown in Figure 3, the random generator has two sockets for the camera outlet, one for the one hundred ten volts needed by the transformer and the other for the connection to the relay in the timing circuit. In operation, the closing of the slide switch, upon contact with a trip pin, sets the time delay circuit in operation, tripping the relay which closes the twenty-four volt secondary circuit connected to the camera. The camera is set in motion; and after a predetermined time interval is past, the relay opens the secondary circuit and the camera stops.